Article type : Original Contribution

Emergency Physicians Are Able to Detect Right Ventricular Dilation with Good Agreement Compared to Cardiology

Matt A. Rutz, MD
Julie M. Clary, MD, MBA
Jeffrey A. Kline, MD
Frances M. Russell, MD, RDMS

MAR, JAK, and FMR – Department of Emergency Medicine, Indiana University School of Medicine, 640 Eskenazi Ave, Indianapolis, IN 46202
JMC – Department of Medicine, Division of Cardiology, Indiana University School of Medicine, E300E Noyes Pavilion, 1800 N Capitol Ave, Indianapolis, IN 46202

Correspondence to Dr. Russell:
640 Eskenazi Avenue
Indianapolis, IN 46202
Phone - (317) 880-3900
Fax - (317) 880-0545
framruss@iu.edu

Running Title – FOCUS RV Dilation

Abstract presented at SAEM Annual Meeting in New Orleans, LA May 12, 2016.

MAR reports no conflict of interest
FMR reports no conflict of interest
JMC reports no conflict of interest

JAK has grant funding from the NIH and Ikaria, is a consultant for Genentech, Stago Diagnostics, Janssen Pharmaceuticals, and owns in CP Diagnostics LLC

Abstract

Objective: Focused cardiac ultrasound (FOCUS) is a useful tool in evaluating patients presenting to the emergency department (ED) with acute dyspnea. Prior work has shown that right ventricular (RV) dilation is associated with repeat hospitalizations and shorter life expectancy. Traditionally, RV assessment has been evaluated by cardiologist-interpreted comprehensive echocardiography. The primary goal of this study was to determine the interrater reliability between emergency physicians (EPs) and a cardiologist for determining RV dilation on FOCUS performed on ED patients with acute dyspnea.

Methods: Prospective, observational study at two urban academic EDs; patients were enrolled if they had acute dyspnea and a computed tomographic pulmonary angiogram without acute disease. All patients had an EP-performed FOCUS to assess for RV dilation. RV dilation was defined as an RV to left ventricular ratio greater than 1. FOCUS interpretations were compared to a blinded cardiologist FOCUS interpretation using agreement and kappa statistics.

Results: Of 84 FOCUS examinations performed on 83 patients, 17% had RV dilation. Agreement and kappa, for EP-performed FOCUS for RV dilation were 89% (95% confidence interval [CI] 80-95%) and 0.68 (95% CI 0.48-0.88), respectively.

Conclusions: EP sonographers are able to detect RV dilation with good agreement when compared to cardiology. These results support the wider use of EP-performed FOCUS to evaluate for RV dilation in dyspneic ED patients.

Introduction

Annually, millions of Americans present to the emergency department (ED) for acute chest pain or dyspnea.[1] Focused cardiac ultrasound (FOCUS), performed at the bedside, has become a vital tool in the evaluation of these patients. Information obtained from a FOCUS examination can aid in the diagnosis, prognosis, and treatment of life threatening pathology.[1-10]

Historically, evaluation of the right ventricle (RV) for size and function was mainly performed by cardiology through comprehensive echocardiography. More recently the American College of Emergency Physicians and American Society of Echocardiography have agreed that assessment for RV strain in the ED is helpful in the diagnosis and prognosis of acute pulmonary embolus (PE) and its use can help to prioritize further testing.[2] Additionally, assessment of RV size is a core skill and integral to the practice of emergency medicine residency graduates.[11] In 2014 Taylor et al.[12] retrospectively looked at the ability of emergency physicians (EPs) to detect RV dilation as a marker for RV strain and found moderate agreement compared to comprehensive echocardiography. More recently, Weekes et al.[5,13] prospectively found that EP-performed FOCUS had excellent overall agreement with comprehensive echocardiography for the detection of RV dysfunction in normotensive patients with acute PE, and that FOCUS was more accurate for detecting early severe RV dysfunction than standard biomarkers such as troponin and brain natriuretic peptide.

More generally, beyond assessment for PE, RV dilation is a marker of increased RV afterload. This pathologic increase in RV afterload can arise from treatable conditions such as idiopathic pulmonary hypertension, chronic obstructive pulmonary disease (COPD), pulmonary artery hypertension, sleep disordered breathing, pulmonary hypertension secondary to left heart disease, or chronic thromboemboli.[14-26] RV dysfunction in any of these conditions worsens prognosis.[16,17,25,27] RV dysfunction, in the absence of PE, is frequently unrecognized in the ED despite the poor outcomes associated with it.[4,14,16-18,21-23,27-29] Prognosis is highly dependent on early detection and proper management. [18,19]

The primary aim of this study was to determine the interrater reliability between EPs and cardiology for determining RV dilation in patients presenting to the ED with acute dyspnea. Secondarily, we assessed interrater agreement for detecting and grading tricuspid regurgitation (TR), and identifying the presence of RV dysfunction. RV dysfunction was defined as RV

dilation and/or moderate to severe TR.[15] We hypothesized that EP's would reliably be able to detect RV dilation.

Methods

Study Setting and Population

This was a prospective, observational study of a convenience sample of adult patients presenting to the ED with acute dyspnea from March 2014 to January 2016. Patients were enrolled at two large urban academic EDs with a combined annual census of > 215,000 patient visits. This study was approved by the Institutional Review Board.

Study Protocol

We included adult patients >18 years old with persistent dyspnea and a non-significant computed tomographic pulmonary angiography (CTPA) scan. Persistent dyspnea was defined as a patient's subjective feeling of being short of breath at rest while breathing their baseline oxygen. A non-significant CTPA scan was defined as no acute disease (i.e. no PE, no pneumonia, etc.). Patients with chronic lung conditions such as COPD and interstitial lung disease were included. The decision to order a CTPA scan followed standard care practices. All CT scans were interpreted by board certified radiologists. A subset of patients had comprehensive echocardiography performed as standard care. These exams were performed by registered diagnostic cardiac sonographers, and final written interpretations were completed by board certified cardiologists with echocardiography fellowship training.

Patients were excluded if they reported a previous diagnosis of RV dysfunction or failure, were being treated for pulmonary hypertension, or declined to participate (Figure 1). Patients were consented and enrolled when a member of the study team or trained sonographer was present in the ED.

All enrolled patients had a FOCUS examination performed using Zonare (ZS3 and Z One Pro, Mindray Zonare, Mountain View, CA) ultrasound machines with the phased array transducer. These studies included the parasternal long axis, parasternal short axis, apical four chamber, subxiphoid, and IVC views by EPs ranging in experience level from postgraduate year (PGY) 1 residents to emergency ultrasound fellowship trained physicians. At our institution, all PGY1 residents undergo a four-week orientation to bedside ultrasound. Each sonographer

underwent an additional one-hour training session with the ultrasound fellowship director focused solely on right heart assessment including RV dilation and TR assessment. FOCUS examinations were performed when study investigators or trained sonographers were present in the ED. This included enrolling patients during clinical shifts and during scanning shifts as part of the resident ultrasound rotation.

Both RV dilation and TR were evaluated using qualitative measurements in the apical four chamber view. The RV was considered to be dilated with an RV to left ventricle (LV) ratio greater than 1 when measured at the base of the RV and LV at end-diastole. TR was graded as none, mild, moderate or severe using color flow Doppler over the tricuspid valve in the apical four chamber view. TR was measured qualitatively by looking at the TR jet area and width.[30,31] We graded severe TR if the regurgitant jet touched the back wall of the right atrium, moderate TR if the jet surpassed 50% of the anterior-posterior diameter of the right atrium, mild if the jet had a small width and was <50% of the anterior-posterior diameter of the right atrium, and none when no jet was visible. We defined RV dysfunction as RV dilation and/or moderate to severe TR. Investigators reported their FOCUS findings on a standardized data collection form, which also included patient demographics and skill level of the sonographer.

Outcome Measures

A board-certified cardiologist with specialty training in echocardiography, blinded to the interpretation of the EP and patient information, reviewed the FOCUS exams. They determined if RV dilation was present or not, and graded TR as none, mild, moderate or severe. They also recorded their confidence level in image quality and interpretation. The cardiologist interpretation served as the criterion standard for this study.

The primary outcome measure of this study was agreement between EPs and the cardiologist on the presence of RV dilation. This was assessed using raw agreement and kappa (κ) statistics. Secondary outcomes assessed agreement using kappa and linear-weighted kappa for the presence and grade of TR, and presence of RV dysfunction, separately. We also compared independently experienced sonographers and novices to cardiology. We defined expert sonographers as EPs with registered diagnostic medical sonographer certification or ultrasound fellowship training. Novices were PGY 1 through 3. Lastly, we compared EP and cardiologist

interpretations of FOCUS exams to comprehensive echocardiography findings in the subset of patients who underwent both exams.

Data Analysis

Data including patient demographics, medical history, FOCUS results, comprehensive echocardiography results (if applicable), and disposition were input into a REDCap database (Vanderbilt Nashville, TN). Statistical analysis was done using Microsoft Excel (Microsoft, Redmond, WA) and VassarStats (http://vassarstats.net Poughkeepsie, NY). Kappa's (κ) and raw agreement were calculated with 95% confidence intervals (CI). A sample size of 50 patients was needed to determine a statistically significant kappa assuming at least 10% prevalence of positive findings, with 80% power to detect a kappa of 0.5 using a 1-tailed test where the null hypothesis states that kappa is zero.

Results

During the study period 84 FOCUS examinations were performed on 83 patients. Of these 84 exams, one had inadequate views to determine RV dilation. Fourteen of 83 exams (17%) had RV dilation. Patient demographics including medical co-morbidities, disposition, and final diagnosis can be found in Table 1. Table 2 lists the number of scans performed based on sonographer experience level. There were 26 different sonographers, 21 were novices and 5 were experienced.

For our primary outcome, comparing EP-performed FOCUS to cardiologist interpretation for RV dilation, the κ value was 0.68 (95% CI 0.48-0.88) for all experience levels, 0.66 (95% CI 0.38-0.93) for novices and 0.67 (95% CI 0.36-0.98) for experienced sonographers. Raw agreement at all experience levels was 89% (95%CI 80-95%). Forty-two of 83 FOCUS examinations (50%) were randomly selected and assessed for EP interobserver reliability. We found 88% (95%CI 73-95%) agreement and a κ=0.70 (95% CI 0.46-0.94) between EPs for RV dilation.

TR assessment was only completed in 57 of 84 examinations (68%). In 7 patients TR evaluation was not feasible and in 20 patients TR assessment was not performed. A subgroup analysis of these 57 patients found a weighted κ=0.61 (95% CI 0.46-0.75) comparing EP FOCUS and cardiologist interpretation. When looking at clinically significant TR (moderate to severe)

κ=0.62 (95% CI 0.36-0.88). Separating out novices from experienced sonographers, the κ=0.74 (95% CI 0.4-1) and 0.54 (95% CI 0.19-0.88), respectively.

The κ values for the presence of RV dysfunction (RV dilation and/or moderate to severe TR) was 0.56 (95% CI 0.36-0.76) overall, 0.55 (95% CI 0.25-0.84) for novices and 0.57 (95% CI 0.29-0.84) for experienced sonographers. Kappa values and raw agreement along with 95% confidence intervals are reported in Table 3.

Forty-four of the 84 patient encounters (52%) had a comprehensive echocardiogram performed within 24 hours of FOCUS. When comparing EP interpretations of FOCUS to comprehensive echocardiography for RV dilation the κ=0.52 (95% CI 0.26-0.78). Agreement for RV dilation was 77% (95%CI 62-88). Similarly, comparing cardiologist interpretations to comprehensive echocardiography for RV dilation κ=0.60 (95% CI 0.35-0.85).

Discussion

The ability to detect RV dilation as a marker of RV dysfunction is important for diagnosis, risk stratification and acute management of ED patients with dyspnea with or without PE. CTPA is able to identify structural vascular abnormalities, but is not reliable enough to rule out RV dysfunction, and is inferior to transthoracic echocardiography for detecting RV dilation.[5,32-34] In patients with PE, findings of RV dilation can expedite treatment and predict hemodynamic collapse in normotensive patients.[4,35-37] Importantly, in patients without PE, RV dysfunction prognosticates worse outcomes, including increased return visits to the ED, repeat unnecessary chest imaging, hospital re-admissions and increased mortality.[14,15,27] Early detection of RV dysfunction, including RV dilation, is critical for improving outcomes.[18,19] In this study, we found good agreement between EP-performed FOCUS and cardiology for identifying RV dilation. This was true regardless of prior ultrasound experience, and with minimal additional training for novice sonographers.

Past studies have looked at agreement between EP-performed FOCUS and comprehensive echocardiography for RV dysfunction. Weekes et al[5] prospectively reported 100% sensitivity and 99% specificity for identification of RV dysfunction in normotensive PE patients. They also found that FOCUS was more accurate for detecting RV dysfunction than standard biomarkers alone. Taylor et al[12] retrospectively found moderate agreement, with a kappa of 0.44, between EP-performed FOCUS and comprehensive echocardiography. These

studies were limited by either a retrospective study design or extensive sonographer level of experience. Our study differs from these prior studies in that we identified symptomatic patients with pulmonary hypertension and RV dysfunction without acute PE. Additionally, we had 26 different sonographers performing FOCUS examinations with 21 being novice sonographers.

Secondarily, we evaluated interrater reliability of EP's to detect and grade TR, as well as RV dysfunction, which we defined as RV dilation and/or moderate to severe TR. For TR we used qualitative measurements in lieu of complex formulas,[38,39] that are performed during comprehensive echocardiography, in order to make this assessment more applicable to general clinical practice. TR was completed in a subset of patients (68%) and overall, we found good agreement when compared to cardiology. Novices ($\kappa = 0.74$) outperformed experienced sonographers ($\kappa = 0.54$). Experienced sonographers were more likely to overcall the presence and grade of TR. For overall RV dysfunction assessment, there was moderate agreement for the presence of RV dysfunction when compared to cardiology. This discrepancy in agreement for RV dysfunction is likely attributable to the difficulties acquiring and grading TR images. Despite the moderate to good agreement for determining RV dysfunction and TR further investigation with more extensive training in TR assessment may be needed.

Over half of the study patients had a comprehensive echocardiogram performed within 24 hours of FOCUS. When comparing EP interpretations of FOCUS and cardiology interpretations of FOCUS to comprehensive echocardiography for RV dilation, we found moderate to good agreement, which is similar to previous literature.[12] These differences in ultrasound interpretations may be the result of the time lag between comprehensive echocardiography and FOCUS image acquisition, due to the quality of FOCUS examinations, or due to the sonographer's level of experience.

This study has shown that EP sonographers, both novice and experienced, can detect RV dilation in patients presenting to the ED with acute dyspnea. The data from our study combined with prior studies shows that EPs are able to detect RV dilation in patients with and without acute PE. These findings on FOCUS in turn may guide acute treatment and disposition. Future research should focus on how findings of RV dysfunction, including RV dilation, impact acute management and long term outcomes in symptomatic patients with and without PE.

Limitations

This study has several limitations that could limit its generalizability. We enrolled a convenience sample of patients when study investigators or trained sonographers were available to perform the FOCUS examinations, which may have introduced selection bias. Sonographers may have been biased as they were not blinded to a patient's physical appearance. This is of minimal significance as patients were covered and clinical gestalt is unreliable for determining etiology of dyspnea.[40] Additionally, in comparing patients with and without RV dilation, there was no statistically significant difference in having a past medical history of COPD. Our small sample size lead to wider confidence intervals, however our results were consistent with prior literature.[5,12] The criterion standard for this study was a single cardiologist interpretation of EP-performed FOCUS exams, and not comprehensive echocardiography. This study design has been used previously.[7,41] Over 50% of study patients had a comprehensive echocardiogram performed as standard care within 24 hours of FOCUS. The time lapse between FOCUS and comprehensive echocardiography limited its utility as a gold standard for this study. Lastly, as part of our study design we did not include patients with acute PE. All of the prior literature on EP's ability to assess RV size and function focuses specifically on patients with acute PE. Our study aimed to assess for RV dilation and dysfunction in persistently symptomatic patients without acute PE, to identify short of breath ED patients with RV dilation and pulmonary hypertension.

Conclusion

Emergency physicians can diagnosis RV dilation on FOCUS with good agreement with cardiology. These results support the wider use of EP-performed FOCUS to evaluate for RV dilation in dyspneic ED patients.

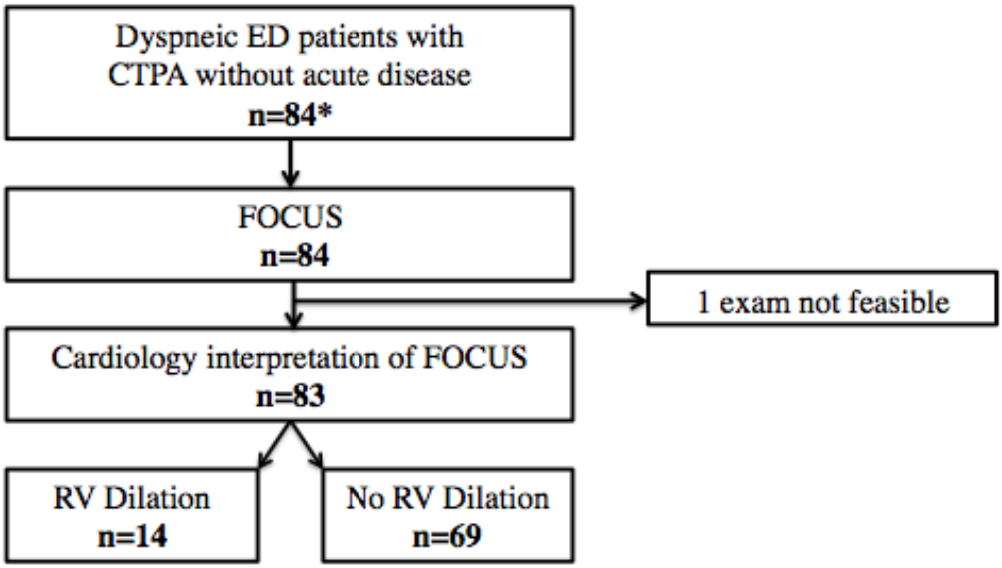
1. Russell FM, Ehrman RR, Cosby K, et al. Diagnosing acute heart failure in patients with undifferentiated dyspnea: a lung and cardiac ultrasound (LuCUS) protocol. Acad Emerg Med 2015;22:182-91.
2. Labovitz AJ, Noble VE, Bierig M, et al. Focused cardiac ultrasound in the emergent setting: a consensus statement of the American Society of Echocardiography and American College of Emergency Physicians. J Am Soc Echocardiogr 2010;23:1225-30.
3. Kreit JW. The impact of right ventricular dysfunction on the prognosis and therapy of normotensive patients with pulmonary embolism. Chest 2004;125:1539-45.

4. Dresden S, Mitchell P, Rahimi L, et al. Right ventricular dilatation on bedside echocardiography performed by emergency physicians aids in the diagnosis of pulmonary embolism. Ann Emerg Med 2014;63:16-24.
5. Weekes AJ, Thacker G, Troha D, et al. Diagnostic Accuracy of Right Ventricular Dysfunction Markers in Normotensive Emergency Department Patients With Acute Pulmonary Embolism. Ann Emerg Med 2016;68:277-91.
6. Zanobetti M, Converti C, Conti A, et al. Prognostic value of emergency physician performed echocardiography in patients with acute pulmonary thromboembolism. West J Emerg Med 2013;14:509-17.
7. Moore CL, Rose GA, Tayal VS, Sullivan DM, Arrowood JA, Kline JA. Determination of left ventricular function by emergency physician echocardiography of hypotensive patients. Acad Emerg Med 2002;9:186-93.
8. Unluer EE, Bayata S, Postaci N, et al. Limited bedside echocardiography by emergency physicians for diagnosis of diastolic heart failure. Emerg Med J 2012;29:280-3.
9. Jackson RE, Rudoni RR, Hauser AM, Pascual RG, Hussey ME. Prospective evaluation of two-dimensional transthoracic echocardiography in emergency department patients with suspected pulmonary embolism. Acad Emerg Med 2000;7:994-8.
10. Nazerian P, Vanni S, Volpicelli G, et al. Accuracy of point-of-care multiorgan ultrasonography for the diagnosis of pulmonary embolism. Chest 2014;145:950-7.
11. Lewiss RE, Pearl M, Nomura JT, et al. CORD-AEUS: consensus document for the emergency ultrasound milestone project. Acad Emerg Med 2013;20:740-5.
12. Taylor RA, Moore CL. Accuracy of emergency physician-performed limited echocardiography for right ventricular strain. Am J Emerg Med 2014;32:371-4.
13. Weekes AJ, Johnson AK, Troha D, Thacker G, Chanler-Berat J, Runyon M. Prognostic Value of Right Ventricular Dysfunction Markers for Serious Adverse Events in Acute Normotensive Pulmonary Embolism. J Emerg Med 2016.
14. Russell FM, Moore CL, Courtney DM, et al. Independent evaluation of a simple clinical prediction rule to identify right ventricular dysfunction in patients with shortness of breath. Am J Emerg Med 2015;33:542-7.
15. Kline JA, Russell FM, Lahm T, Mastouri RA. Derivation of a screening tool to identify patients with right ventricular dysfunction or tricuspid regurgitation after negative computerized tomographic pulmonary angiography of the chest. Pulm Circ 2015;5:171-83.
16. Chaouat A, Naeije R, Weitzenblum E. Pulmonary hypertension in COPD. Eur Respir J 2008;32:1371-85.
17. Wells JM, Washko GR, Han MK, et al. Pulmonary arterial enlargement and acute exacerbations of COPD. N Engl J Med 2012;367:913-21.
18. Galie N, Hoeper MM, Humbert M, et al. Guidelines for the diagnosis and treatment of pulmonary hypertension: the Task Force for the Diagnosis and Treatment of Pulmonary Hypertension of the European Society of Cardiology (ESC) and the European Respiratory Society (ERS), endorsed by the International Society of Heart and Lung Transplantation (ISHLT). Eur Heart J 2009;30:2493-537.
19. McLaughlin VV, Shah SJ, Souza R, Humbert M. Management of pulmonary arterial hypertension. J Am Coll Cardiol 2015;65:1976-97.
20. McLaughlin VV, Archer SL, Badesch DB, et al. ACCF/AHA 2009 expert consensus document on pulmonary hypertension: a report of the American College of Cardiology Foundation Task Force on Expert Consensus Documents and the American Heart Association:

developed in collaboration with the American College of Chest Physicians, American Thoracic Society, Inc., and the Pulmonary Hypertension Association. Circulation 2009;119:2250-94.
21. Zakir RM, Al-Dehneh A, Maher J, Saric M, Berkowitz RL. Right ventricular failure in patients with preserved ejection fraction and diastolic dysfunction: an underrecognized clinical entity. Congest Heart Fail 2007;13:164-9.
22. van de Veerdonk MC, Kind T, Marcus JT, et al. Progressive right ventricular dysfunction in patients with pulmonary arterial hypertension responding to therapy. J Am Coll Cardiol 2011;58:2511-9.
23. Voelkel NF, Quaife RA, Leinwand LA, et al. Right ventricular function and failure: report of a National Heart, Lung, and Blood Institute working group on cellular and molecular mechanisms of right heart failure. Circulation 2006;114:1883-91.
24. Harjola VP, Mebazaa A, Celutkiene J, et al. Contemporary management of acute right ventricular failure: a statement from the Heart Failure Association and the Working Group on Pulmonary Circulation and Right Ventricular Function of the European Society of Cardiology. Eur J Heart Fail 2016;18:226-41.
25. Rivera-Lebron BN, Forfia PR, Kreider M, Lee JC, Holmes JH, Kawut SM. Echocardiographic and hemodynamic predictors of mortality in idiopathic pulmonary fibrosis. Chest 2013;144:564-70.
26. Cottin V, Le Pavec J, Prevot G, et al. Pulmonary hypertension in patients with combined pulmonary fibrosis and emphysema syndrome. Eur Respir J 2010;35:105-11.
27. Chen AA, Wood MJ, Krauser DG, et al. NT-proBNP levels, echocardiographic findings, and outcomes in breathless patients: results from the ProBNP Investigation of Dyspnoea in the Emergency Department (PRIDE) echocardiographic substudy. Eur Heart J 2006;27:839-45.
28. Wilcox SR, Kabrhel C, Channick RN. Pulmonary Hypertension and Right Ventricular Failure in Emergency Medicine. Ann Emerg Med 2015;66:619-28.
29. Boerrigter BG, Bogaard HJ, Trip P, et al. Ventilatory and cardiocirculatory exercise profiles in COPD: the role of pulmonary hypertension. Chest 2012;142:1166-74.
30. Rivera JM, Vandervoort PM, Morris E, Weyman AE, Thomas JD. Visual assessment of valvular regurgitation: comparison with quantitative Doppler measurements. J Am Soc Echocardiogr 1994;7:480-7.
31. Zoghbi WA, Enriquez-Sarano M, Foster E, et al. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography. J Am Soc Echocardiogr 2003;16:777-802.
32. Dudzinski DM, Hariharan P, Parry BA, Chang Y, Kabrhel C. Assessment of Right Ventricular Strain by Computed Tomography versus Echocardiography in Acute Pulmonary Embolism. Acad Emerg Med 2016.
33. Devaraj A, Hansell DM. Computed tomography signs of pulmonary hypertension: old and new observations. Clin Radiol 2009;64:751-60.
34. Lang IM, Plank C, Sadushi-Kolici R, Jakowitsch J, Klepetko W, Maurer G. Imaging in pulmonary hypertension. JACC Cardiovasc Imaging 2010;3:1287-95.
35. Goldhaber SZ, Visani L, De Rosa M. Acute pulmonary embolism: clinical outcomes in the International Cooperative Pulmonary Embolism Registry (ICOPER). Lancet 1999;353:1386-9.
36. Grifoni S, Olivotto I, Cecchini P, et al. Short-term clinical outcome of patients with acute pulmonary embolism, normal blood pressure, and echocardiographic right ventricular dysfunction. Circulation 2000;101:2817-22.

37. Kasper W, Konstantinides S, Geibel A, Tiede N, Krause T, Just H. Prognostic significance of right ventricular afterload stress detected by echocardiography in patients with clinically suspected pulmonary embolism. Heart 1997;77:346-9.
38. Jaff MR, McMurtry MS, Archer SL, et al. Management of massive and submassive pulmonary embolism, iliofemoral deep vein thrombosis, and chronic thromboembolic pulmonary hypertension: a scientific statement from the American Heart Association. Circulation 2011;123:1788-830.
39. Gifford RW, Jr., Groves LK. Limitations in the feasibility of pulmonary embolectomy. A clinicopathologic study of 101 cases of massive pulmonary embolism. Circulation 1969;39:523-30.
40. Mueller C, Frana B, Rodriguez D, Laule-Kilian K, Perruchoud AP. Emergency diagnosis of congestive heart failure: impact of signs and symptoms. Can J Cardiol 2005;21:921-4.
41. Ehrman RR, Russell FM, Ansari AH, et al. Can emergency physicians diagnose and correctly classify diastolic dysfunction using bedside echocardiography? Am J Emerg Med 2015;33:1178-83.

Figure 1



*One patient is counted twice as 2 FOCUS exams were performed by different sonographers during different ED visits for dyspnea. CTPA – Computerized tomography pulmonary angiography, FOCUS – focused cardiac ultrasound, RV – right ventricular

Table 1. Patient Characteristics

	RV Dilation (n=14)	No RV Dilation (n=69)
Demographics		
Age (yr) Avg (range)	63.7 (50-88)	52.9 (23-85)
Male (%)	7 (50)	29 (42)
Avg BMI (kg/m2)	29.0	33.7
Ethnicity (%)		
White	8 (57)	31 (44)
Black	5 (36)	32 (46)
Hispanic	1 (7)	5 (7)
Other*	0 (0)	1 (1)
Co Morbidities (%)		
COPD/Asthma	7 (50)	31 (45)
Interstitial Lung Disease	1 (7)	4 (6)
Tobacco Use (current or quit)	10 (71)	39 (57)
CAD	4 (29)	10 (14)
Heart Failure	5 (36)	9 (13)
History of PE	0 (0)	12 (17)
OSA	2 (14)	8 (12)
Labs		
Avg BNP (n)+	877 (12)	349 (39)
Disposition (%)		
ICU	2 (14)	9 (13)
Stepdown	0 (0)	4 (6)
Telemetry bed	11 (79)	23 (33)

Unmonitored bed	0 (0)	13 (19)
Observation	1 (7)	11 (16)
Discharge	0 (0)	9 (13)
Final Diagnosis (%)		
CHF	1 (7)	7 (10)
COPD/Asthma	1 (7)	14 (20)
ACS	2 (14)	3 (4)
CP/SOB	0 (0)	19 (28)
PNA	0 (0)	7 (10)
Pulmonary Hypertension	9 (64)	9 (13)
Other	1 (7)	10 (14)
Ultrasound (%)		
Novice	8 (57)	24 (35)
Expert	6 (43)	45 (65)

*Patients identified as other, declined, or were not recorded
[+] Not all patients had BNP drawn as it was left to the discretion of treating physician.
ACS = acute coronary syndrome, Avg = average, BMI = body mass index, BNP = brain natriuretic peptide, COPD = chronic obstructive pulmonary disease, CP = chest pain, ICU = intensive care unit, RV = Right Ventricle, SOB = shortness of breath, yr = years

Table 2. Experience Level and Number of Scans

	n	Percentage (%)
Ultrasound Faculty	39	47
Ultrasound Fellows	11	13
PGY 3	8	10
PGY2	7	8
PGY1	18	22

PGY = post graduate year

Table 3. Comparison of emergency physician to cardiologist interpretations *

	n	Kappa (95%CI)	Agreement (95%CI)
RV Dilation	83	0.68 (0.48-0.88)	89% (80-95%)
Novice	34	0.66 (0.38-0.93)	85% (68-95%)
Expert	49	0.67 (0.36-0.97)	92% (80-97%)
Tricuspid Regurgitation^{+}	57	0.62 (0.36-0.88)	88% (76-95%)
Novice	20	0.74 (0.4-1)	90% (67-98%)
Expert	37	0.54 (0.19-0.88)	86% (70-95%)
RV Dysfunction	56	0.57 (0.33-0.81)	82% (69-91%)
Novice	20	0.78 (0.50-1)	90% (67-98%)
Expert	36	0.43 (0.08-0.78)	78% (60-89%)

CI = confidence interval, RV = right ventricular, *Refers to number of patients with images allowing these measurements, $^{+}$Clinically significant tricuspid regurgitation

Table 4. Two by Two tables comparing ED interpretation of FOCUS to cardiology interpretation

Right Ventricular Dilation

		Cardiology		
		+	-	Total
ED	+	13	8	21
	-	1	61	62
	Total	14	69	83

Tricuspid Regurgitation*

		Cardiology		
		+	-	Total
ED	+	42	1	43
	-	6	8	14
	Total	48	9	57

Right Ventricular Dysfunction

		Cardiology		
		+	-	Total
ED	+	11	9	20
	-	1	35	36
	Total	12	44	56

*Clinically significant tricuspid regurgitation. FOCUS – Focused cardiac ultrasound